NEMA Standards Publication

NEMA MS 3-2008 (R2014, R2020)

Standard for Determination of Image Uniformity in Diagnostic Magnetic Resonance Images

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National Electrical Manufacturers Association

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Determination of Image Uniformity
in Diagnostic Magnetic Resonance Images

Published by:

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, VA 22209

www.nema.org

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Preamble

This is one of a series of test Standards developed by the medical diagnostic imaging industry for the measurement of performance parameters governing image quality of magnetic resonance (MR) imaging (MRI) systems. These test Standards are intended for the use of equipment manufacturers, prospective purchasers, and users alike.

Manufacturers are permitted to use these Standards for the determination of system performance specifications. This standardization of performance specifications is of benefit to the prospective equipment purchaser, and the parameters supplied with each NEMA measurement serve as a guide to those factors that can influence the measurement. These Standards can also serve as reference procedures for acceptance testing and periodic quality assurance.

It must be recognized, however, that not all test Standards lend themselves to measurement at the installation site. Some test Standards require instrumentation better suited to factory measurements, while others require the facilities of an instrumentation laboratory to assure stable test conditions necessary for reliable measurements.

The NEMA test procedures are carried out using the normal clinical operating mode of the system. For example, Standard calibration procedures, Standard clinical sequences and Standard reconstruction processes shall be used. No modifications to alter test results shall be used unless otherwise specified in these Standards.

The NEMA Magnetic Resonance Section has identified a set of key magnetic resonance image quality parameters. This Standards publication describes the measurement of one of these parameters.

Equivalence

It is intended and expected that manufacturers or others who claim compliance with these NEMA Standard test procedures for the determination of image quality parameters shall have carried out the tests in accordance with the procedures specified in the published Standards.

In those cases where it is impossible or impractical to follow the literal prescription of a NEMA test procedure, a complete description of any deviation from the published procedure must be included with any measurement claimed equivalent to the NEMA Standard. The validity or equivalence of the modified procedure will be determined by the reader.

Uncertainty of the Measurements

The measurement uncertainty of the image quality parameter determined using this Standards publication is to be reported together with the value of the parameter. Justification for the claimed uncertainty limits shall also be provided by a listing and discussion of sources and magnitudes of error.

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Foreword

This Standards publication is classified as a NEMA Standard unless otherwise noted. It is intended for use by MRI system manufacturers, manufacturers of accessory equipment (including radio-frequency coils), and by MRI end users.

The purpose of this Standards publication is to provide a Standard procedure for measuring and reporting image-intensity uniformity in an MRI system.

Image uniformity refers to the ability of an MR imaging system to produce an identical signal response throughout the scanned volume when the object being imaged is homogenous. Image-intensity non-uniformity in a two-dimensional MR image of a uniform test object can be caused by a number of factors, including RF coil geometry and penetration, non-uniformity of the transmitted RF field (B_1 non-uniformity), inhomogeneity of the static magnetic field (B_0 non-uniformity), inadequacies in gradient pulse calibration or eddy current corrections, and spatial positioning of the phantom.

Image uniformity is quantified here in terms of the deviation of the image pixel intensities from the midrange value. The analysis of uniformity shall be performed over the region of interest that is typically occupied by clinical samples and not over the full available volume of the RF coil.

This Standards publication has been developed by the Magnetic Resonance Section of the National Electrical Manufacturers Association. User needs have been considered throughout the development of this publication. Proposed or recommended revisions should be submitted to:

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Section approval of the Standard does not necessarily imply that all section Members voted for its approval or participated in its development. At the time it was approved, the section was composed of the following Members:

Computer Imaging Reference Systems—Norfolk, VA
GE Healthcare, Inc.—Milwaukee, WI
Hitachi Medical Systems America, Inc.—Twinsburg, OH
Invivo—Gainesville, FL
Philips Healthcare—Andover, MA
Siemens Medical Solutions, Inc.—Malvern, PA
Toshiba American Medical Systems—Tustin, CA

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Rationale

This Standard measure image non-uniformity (see 1.3) to characterize the low spatial frequency non-uniformities typical of MR images. It is important to quantify image non-uniformity because it alters image contrast.

Various factors influence MR image non-uniformity such as B1 non-uniformity (both in transmit and receive), quality of B0 shim, geometric distortion, etc. Various techniques exist to correct for some forms of image non uniformity such as RF receive coil correction algorithms.

The use of geometric distortion correction algorithms and image uniformity correction algorithms is becoming increasingly common, and in some situations necessary. Both types of corrections will alter image uniformity results reported in this Standard. While it was the original intent of this Standard to characterize the coil without these corrections, it is also the intent of the Standard to test the coil under typical clinical conditions. Therefore, the results will be reported both ways where possible.

This Standard characterizes image non-uniformity qualitatively with a gray-scale uniformity map and quantitatively with simple figures of merit that analyze the range of pixel intensities relative to some measure of the average image intensity.

Scope

This document defines a method for measuring image-uniformity performance of diagnostic magnetic resonance imaging systems using single channel volume coils and performing proton imaging. This document does not address the use of surface coils, chemical shift imaging, or spectroscopy.

Image uniformity can be characterized in a number of different ways. The choice of a measurement and reporting method was guided by a desire for simplicity, accuracy, and ease of implementation on all MR systems. The peak deviation method represents a single image test that can quickly determine and report uniformity with a single number. It works best with very high SNR images. The gray-scale uniformity map image represents a single image test that can visually describe image uniformity. Both the ACR MR Accreditation Procedure method and the Normalized Absolute Average Deviation method resolve some of the image SNR issues of the peak deviation method.

Measurements are made over a volume that is representative of the region used for typical clinical studies. Due to the difficulty in handling large phantoms, it is permitted to use a test phantom that only covers 85% of the specification area.

This document does not address the use of special purpose coils (see MS 6) or coils that require multiple receiver channels for operation (see MS 9).

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